AMPUTATION NEUROMA IN NERVES IMPLANTED IN BONE*

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WAR, the greatest single agent responsible for amputation, invariably stimulates interest in and a study of the problem of painful amputation neuroma. The various hypotheses advanced to account for the pain which occurs in a small percentage of these neuromas include: Inflammation and ascending neuritis; strangulation of the neuraxes in contracting scar; fixation of nerve ends in muscle; and repeated trauma.[1] Treatment has been signally unsatisfactory; hence attention has been directed toward prevention of the neuroma or at least a minimization of its size and vulnerability. That such efforts have not been entirely successful is shown by the legion of suggested approaches to the problem.

Probably the oldest preventive method, one still commonly recommended, consists of pulling down the nerve as far as it will conveniently stretch, cutting it with a sharp scalpel and allowing the proximal end to retract into the areolar tissue well above the end of the stump.[2, 3] Bardenheuer[4] (1908) modified this method by turning the cut end of the nerve back and implanting it beneath the sheath of the same nerve higher up, forming a loop. Krüger[5] (1916) merely crushed the nerve in forceps. Sicard[6] (1916) felt that sensory fibers only would be destroyed by 60 per cent alcohol and recommended its use. Chapple[7] (1917) turned back an epineurial cuff several millimeters in width, cut off the neuraxes and pulled down the cuff, tying it below the cut ends. Moscowicz[8] (1918) inserted the end of the nerve into muscle. Corner[9] (1918) excised an inverted wedge to form a "swinging door flap," the edges of which were sutured together. Hedri[10] (1920) used the cautery to seal the end of the nerve and prevent the irritating effect of secretions from the wound. Huber and Lewis[11] (1920) tied off the nerve and injected about one cubic centimeter of absolute alcohol from one to three centimeters above the site of the ligature. Stookey (1922) recommended a combination of Corner's swinging door flap and the injection of absolute alcohol. Läwen[12] (1925) used refrigeration. Foerster[13] (1927) injected 5 per cent formalin into the central stump. Beswerschenko[14] (1929) recommended Federoff's method of phenolization of the end of the nerve and the injection of liquid phenol into the stump above the cut end. Lexer[15] (1931) tried electrocoagulation.

In reviewing this array of therapeutic proposals, it seemed noteworthy that the procedure of inserting the end of the cut nerve into the bone, invariably adjacent in amputations, had apparently not been tried by any of these

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authors. Lewis[11] saw one instance of a divided nerve in which the ends had been driven into the bone—no neuroma was formed, and he believed that the surrounding bone prevented the formation of a bulb. Other relevant comment was not found in the literature. Craig and Walker[16] (1942) observed a situa-

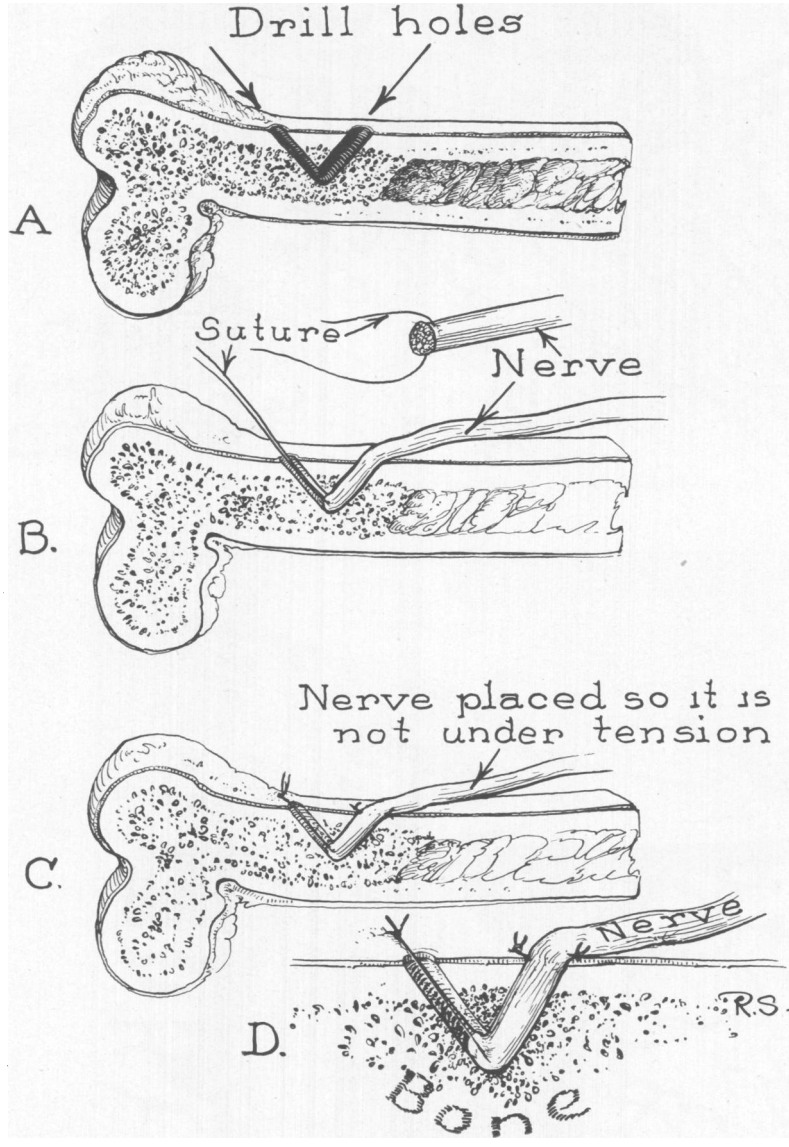

FIG. 1.—Technic for implantation of nerve into bone.

tion similar to that noted by Lewis, in the arm of a patient wounded in the current war.

With these points in mind, an experimental approach to the problem was begun in April, 1942. It was decided to insert the ulnar nerve into a hole in

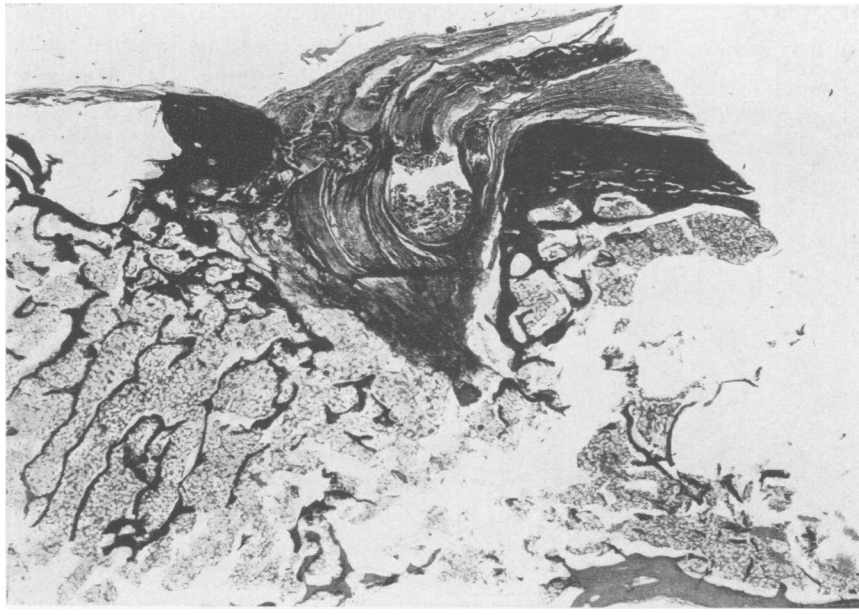

FIG. 2.—Photomicrograph of intra-osseous amputation neuroma after 133 days. (× 6)

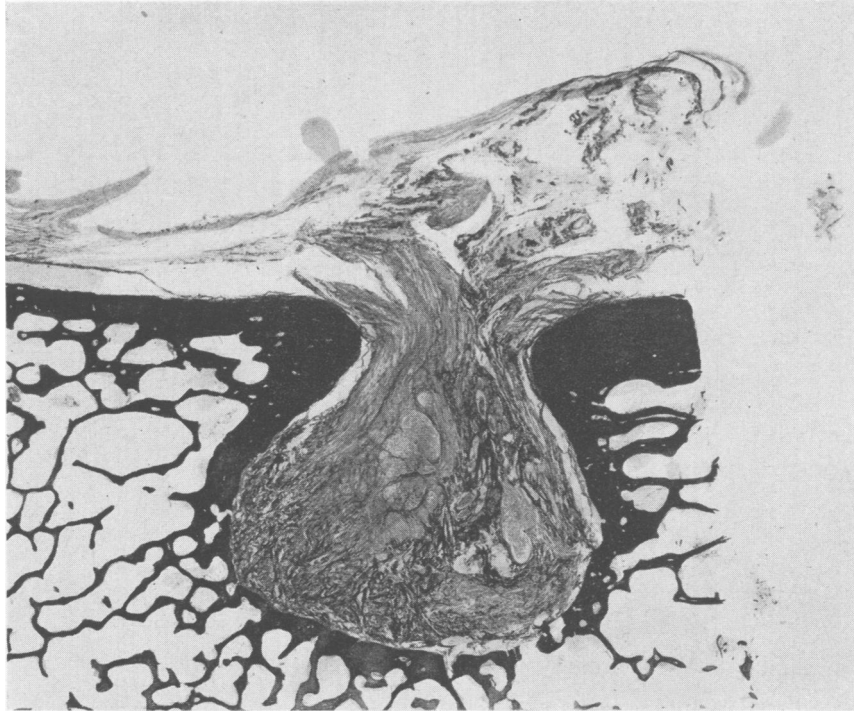

FIG. 3.—Photomicrograph of intra-osseous amputation neuroma after 299 days. (× 6)

the distal portion of the humerus in dogs, and to observe the resulting amputation neuroma after the elapse of approximately 250 to 300 days—a figure chosen arbitrarily.

Six large dogs were used. In each, the right ulnar nerve was exposed just over the distal end of the humerus. A hole large enough to contain the nerve was drilled into the cancellous bone above the joint and the nerve was cut and inserted into the opening, being held in place by fine cotton sutures placed between the periosteum and the perineurium. Fearing that the nerve might pull out—a fear substantiated later in two cases—a minor change was made in the last two experiments. A second, smaller hole was drilled into the bone below the first at an angle such that the two connected at the bottom of the

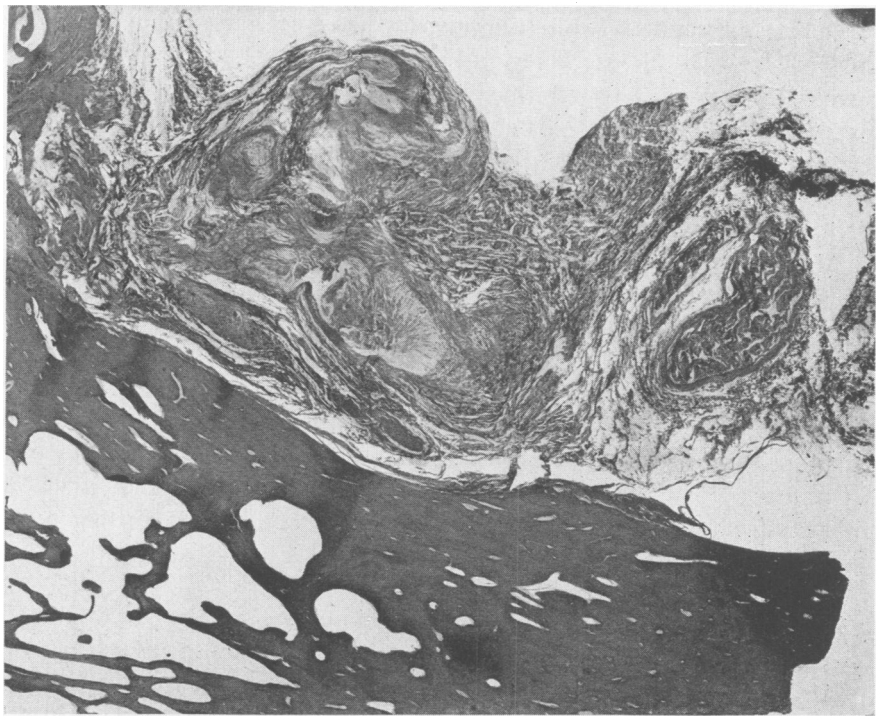

FIG. 4.—Photomicrograph of amputation neuroma 318 days after operation. The nerve had pulled out of its intra-osseous position. (× 6)

cavity of the larger hole. A suture was then passed through the perineurium and threaded through the two holes in the bone so that, by pulling on the suture, the cut end of the nerve was drawn into the depth of the opening and could be held there by attaching this suture snugly to the periosteum about the smaller hole. As in the earlier animals, stay-sutures between the periosteum of the larger hole and the adjacent perineurium were also used (Fig. 1).

The first dog on which this last technic was used was killed after only 133 days. Sections parallel with the long axis of the bone showed the neuroma to be small and completely beneath the cortex of the bone (Fig. 2).

The remaining animals were killed in from 262 to 318 days. The other dog upon which the modified technic was used had a small neuroma, completely subcortical, after 299 days (Fig. 3). Two dogs in which the single-hole technic was used had only small neuromas, though somewhat larger than the one just mentioned. In one of these, after 276 days, the neroma had burrowed deep into the bony tissue. Apparently a deeper cavity had been made in this instance. In a dog kept for 262 days, a cyst had replaced the distal one-third of the neuroma.

The two dogs in which the ulnar nerve had pulled out served as admirable controls. These were the first to be operated upon and their time of survival was slightly longer—318 and 314 days. In these two instances the neuromas were from two to four times the size of the buried neuromas (Fig. 4).

During the course of this study the method was employed by Dr. K. O. Haldeman and Dr. Helen Hagey, of the Department of Orthopedics, in a case in which amputation was performed through the humerus because of a distally located malignant tumor. After five months there was no demonstrable neuroma in any of the nerves. The method has been used since in amputations carried out on the University of California Surgical Service at the San Francisco Hospital, thus far with no reported unsatisfactory results.

At present, studies are being made of the implantation of nerves into the fatty marrow and of combining the implantation of the nerve into bone with the injection of sclerosing agents to reduce further in size the ends of the cut nerves.

Statements concerning the value of implantation of the cut end of a nerve into bone for the prevention of painful amputation neuroma cannot be made at the present time. It can be concluded, however, that the method described is practicable, that the resulting neuroma will be small and that it will be protected from traumatic and toxic influences. On this basis further use of the method seems to be indicated.

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